NACA

RESEARCH MEMORANDUM

HYDRODYNAMIC CHARACTERISTICS OF MISSILES LAUNCHED UNDER WATER

By John R. Dawson

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

June 27, 1958

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

HYDRODYNAMIC CHARACTERISTICS OF MISSILES LAUNCHED UNDER WATER

By John R. Dawson

SUMMARY

Some of the hydrodynamic problems associated with the launching of an air missile from under water are examined briefly. From a limited hydrodynamic investigation that has been made in this field, some experimental results are presented to illustrate the problems that may be expected.

INTRODUCTION

Much interest is currently being given to the possibility of launching an air missile from a submerged submarine in such a manner that the missile rockets can be fired after the missile emerges from the water surface. In order to examine some of the problems encountered in such launchings, the NACA has made some hydrodynamic experiments in Langley tank no. 2 with a dynamic model of a typical missile.

SYMBOLS

d	depth of launching catapult
t	time after emergence
ϕ	launch angle (cant of launching tube)
θ	angle of deviation of missile from vertical
$\theta_{1\,SEC}$	angle of maximum deviation 1 second after emergence

APPARATUS AND PROCEDURE

Experiments have been made with a small-scale dynamic model representative of a suitable missile configuration (fig. 1). The weight, moment of inertia, and center-of-gravity location of the model were scaled from representative full-scale values.

The launching method used is illustrated in the sketch included in figure 2. As is shown, the missile was launched by means of a submerged catapult. This simple catapult used compressed air in a manner currently being considered for full-scale launching, but it was not a model of any particular full-scale catapult. The catapult was placed on a small carriage which was towed along underwater rails by means of an electric winch when it was desired to simulate the forward motion of the submarine. A few tests were made with the catapult tube inserted in a streamline body as shown in figure 2, but it was determined that for the submarine speeds under investigation, the effect produced by this body was small, and most of the tests were made with the launching tube alone. The deviation of the model from the vertical after emerging from the water, designated the angle θ, was determined from motion-picture frames.

RESULTS AND DISCUSSION

A short motion-picture film supplement illustrating the effects discussed in this paper is available on loan. A request card form and a description of the film will be found at the back of this paper, on the page immediately preceding the abstract and index page.

The data in figure 2 are for a launching depth of 100 feet and an emergence speed of 90 feet per second. All values shown are scaled up to represent full-scale values. The deviation angle θ is plotted against time after emergence from the water surface. It is, of course, necessary that the angle θ be within limits that will permit control by the missile guidance system at the time when the rockets are fired. Each test point shown represents the maximum deviation obtained from a group of test runs made for each condition. In the calm-water condition only random disturbances affect the model, which is statically unstable, and the area shown represents a cross section of the cone of dispersion of θ values. It is advantageous to fire the rockets as soon as possible after the missile emerges, because of the increase in deviation with time. The value of θ 1 second after emergence (representing a reasonable delay for rocket firing) is used as a simple figure of interest. The 12-foot wave introduced maximum angular deviations (after 1 second) of about 20° more than the 8° obtained in calm water. The water in a wave crest moves in the direction of the wave train while that in the trough moves in the opposite direction. Accordingly, emergences through the crest and through the trough gave deviation angles in opposite directions but of about the same magnitude.

The effect of the forward speed of the submarine is shown in figure 3, where the maximum angle of deviation 1 second after emergence (designated $\theta_{1\ SEC}$) in calm water is plotted against the vessel's speed of advance. These data were taken with the launching tube vertical. The launching vessel was traveling on rails and its reactions from the catapulting forces were therefore negligible. In all cases the deviation angle was opposite to the direction of the vessel's forward motion. At 3 knots the deviation was about 45° and even at 1 knot the deviation was more than twice that obtained in the static condition. The advantage of getting the submarine speed down to a low value is emphasized by these data.

The curved path of the missile, when the submarine is under way, can be made more nearly tangent to the vertical after emergence by canting the launching tube forward at a launch angle ϕ as shown in figure 4. The data in this figure are for a "hovering" speed of 1 knot. Under the conditions shown, the deviation was least at a launch angle of about 6°, for which case the measured deviation 1 second after emergence was 12°. Thus, about half the deviation introduced by the 1-knot forward speed has been recovered by canting the launching tube at optimum launch angle. Although the optimum angle is not critical, the practical use of this trend will depend on the accuracy with which the submarine trim can be maintained. Somewhat similar results would be expected if the submarine itself instead of the launching tube in the submarine were inclined at the launch angle.

In figure 5 the effect of launching depth is shown. For these data the launching vessel was fixed and the speed of emergence from the water surface was maintained constant at 90 feet per second. A rapid increase in the deviation angle occurred with increase of depth. At depths greater than 200 feet the model would not consistently emerge from the water.

The model tests reviewed here were made at scale speeds, for which no cavitation occurred. At actual full-scale speeds of the order of 90 feet per second, appreciable cavitation has been observed on a missile of this shape. Force tests made in Langley tank no. 2 and in the Langley high-speed hydrodynamic facility have indicated relatively small effect of this cavitation on static stability. Effects of cavitation on dynamic stability have not yet been evaluated.

While the actual values of deviations indicated in this investigation might perhaps be reduced by refinements in catapulting techniques that reduce the initial disturbances, there still remain unavoidable disturbances due to motions of the sea and of the launching vessel. These brief experiments have indicated that such environmental disturbances have substantial effects, and the limits in operating conditions for satisfactory missile launching may therefore be imposed by hydrodynamic behavior. Where these operating limits are found to be too restrictive, it would be logical to increase the stability of the missile with tail fins or other devices.

CONCLUDING REMARKS

The effects of some pertinent operating parameters on the behavior of an air missile when launched from a submerged submarine have been examined experimentally. It was found that for the case of a typical unstable missile, the motions of the sea and of the launching vessel, as well as the depth of the launching catapult, had considerable effect on the attitude that the missile would have at the time its rockets are fired.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 18, 1958.

MISSILE CONFIGURATION

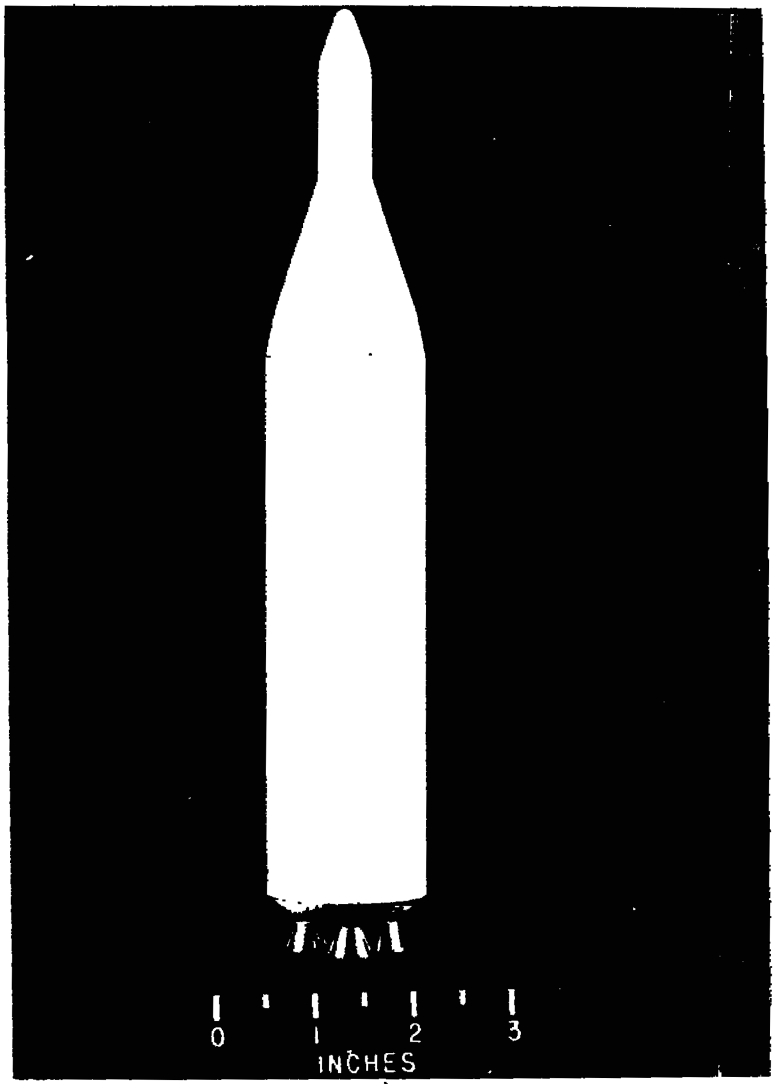

Figure 1 L-58-1022

EFFECT OF WAVES ON UNDERWATER LAUNCHING
SUBMARINE SPEED, ZERO; VALUES ARE FULL SCALE

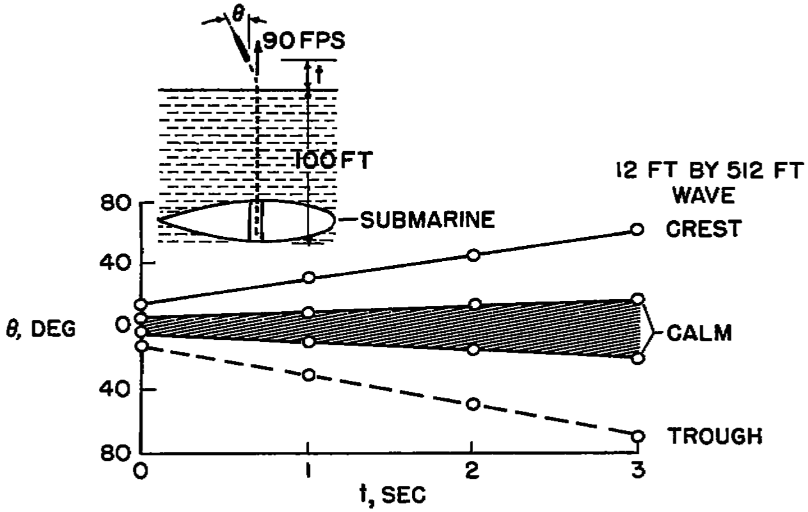

Figure 2

EFFECT OF SUBMARINE SPEED
ON VERTICAL UNDERWATER LAUNCHING
VALUES ARE FULL SCALE

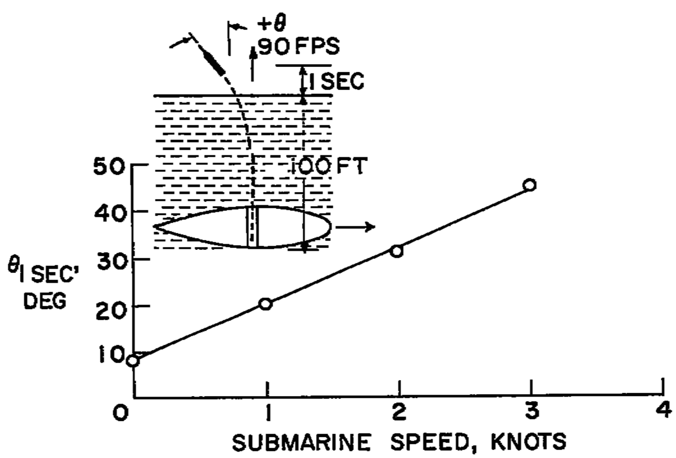

Figure 3

EFFECT OF LAUNCH ANGLE ON UNDERWATER LAUNCHING
SUBMARINE SPEED, 1 KNOT; VALUES ARE FULL SCALE

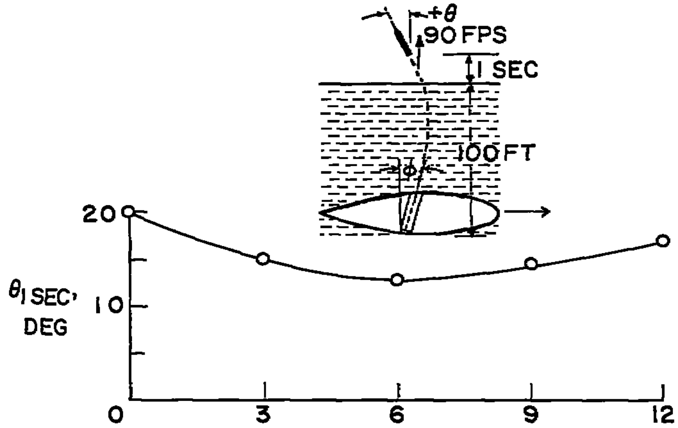

Figure 4

EFFECT OF DEPTH ON UNDERWATER LAUNCHING
SUBMARINE SPEED, ZERO; VALUES ARE FULL SCALE

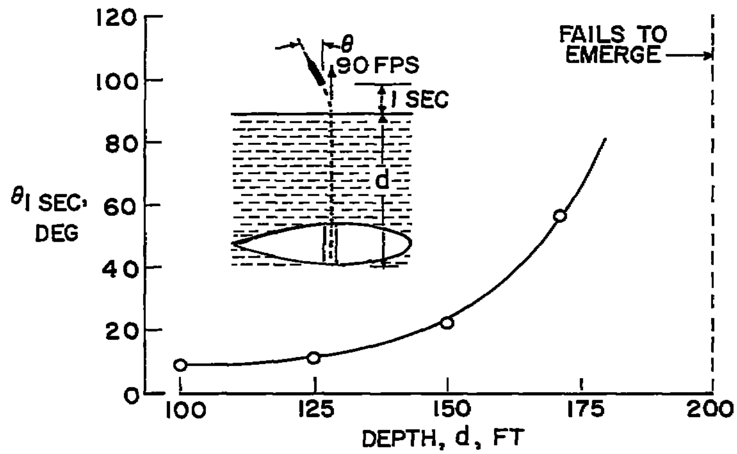

Figure 5

UNCLASSIFIED

UNCLASSIFIED

~~CONFIDENTIAL~~